Approximate Horizon Detection Method based on VMD in Highway Environment

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Abstract—**This paper proposed a detection method of approximate horizon in highway environment. The horizon is detected by using Vertical Mean Distribution (VMD) in the image. Since road is below the horizon, the horizon detection is very important for fast computation of road lane, obstacle, etc. The conventional horizon detection by using minimum VMD is often failed by large objects like road sign, etc. In this paper, horizontal detection accuracy is greatly improved. The performance of proposed method is empirically verified for various environments such as road sign, dark roads, etc.**

Keywords-component; ADAS, horizon, ROI, detection

I. INTRODUCTION

In recent years, automotive IT convergence technology research is emphasized in the technique of Intelligent Vehicles. The research of the various systems, that assist the driver and convenience of drivers for the prevention of traffic accidents, have been made. These systems are called ADAS (Advance Driver Assistant System). LKAS (Lane Keeping Assistant System) and LDWS (Lane Departure Warning System) are important functions in the ADAS [1]. Since those systems should be operated in real time, ROI (Region of Interest) definition is necessary. The horizontal line detection for ROI definition is necessary for high-speed calculation of the LKAS and LDSW.

The Lim's method is using VMD (Vertical Mean Distribution) for determining the location of horizon. In the method, the first minimum VMD value which occurred from the upper curve is considered as horizon [2][3]. And Tran's iVMD (Improved VMD) extends the concept of Lim's method to detect the horizon at the night [4]. However, these conventional methods show the limited performance for the image with the obstacles like cloud, traffic and traffic sign. Those obstacles affect on the VMD patterns, resulting in a significant difference between the detection results and the actual horizon, because those obstacles have the possibility to affect on the VMD.

In this paper, a modified VMD-based horizon detection method is used to solve the above problems. Since the region of road and sky is located in the bottom and top, a line, which connects between the top and bottom points, can be a reference line regardless of the cloud, obstacles and road sign in the image. The proposal method determines a horizon location by using difference between this reference line and VMD value.

This paper is organized as: Section II discusses about the conventional VMD-based horizon detection method, while Section III explains the proposal algorithm. Several simulation results are shown in Section IV. Our conclusions are drawn in Section V.

II. CONVENTIONAL VMD-BASED HORIZON DETECTION METHOD[3]

Conventionally, an image is divided into sky region and road region using VMD. VMD is measured by averaging the gray values of each row on the image. The threshold value of regional dividing line is acquired through a minimum search along the vertical mean curve, where the first minimum occurs from the upper curve is the horizon. This is because sky region usually possesses higher intensity than road pixels, and it might have a big jump of intensity difference as sky pixels approached ground. VMD and horizon detection are defined as the following equation.

$$VMD(i) = \frac{1}{W}\sum_{j=1}^{W} Gray(i,j),\ i \in (1,H) \tag{1}$$

$$Horizon = \underset{i}{argmin}\, VMD(i),\ i \in (1,H) \tag{2}$$

where Gray(i, j) is intensity of the pixel at the i-th row and j-th column in grayscale image converted from original image. W and H are the width and height of original image. VMD(i) is the average of the intensity values of the i-th row. Fig.1 (a) is shown the result of minimum VMD detection method, Fig.1 (b) demonstrate the VMD. The cyan marker is meant a horizon.

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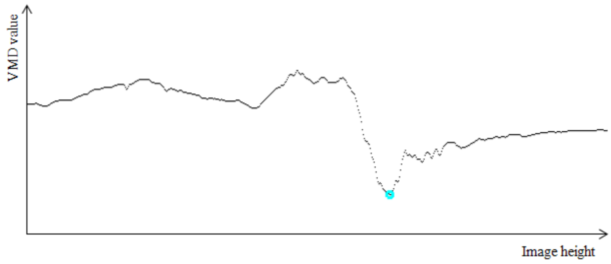
(a)



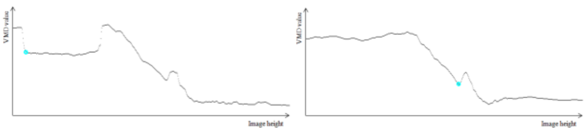
(b)

Figure 1. Conventional VMD-based horizon detection; (a) the results of minimum VMD detection method and (b) VMD

III. PROPOSED METHOD VMD-BASED HORIZON DETECTION METHOD

The conventional detection algorithm using minimum VMD is not adapted for a variety of the driving environments. These methods show the limited performance for the image with the obstacles like cloud, traffic and traffic sign. Those obstacles affect on the VMD patterns, resulting in a significant difference between the detection results and the actual horizon, because those obstacles have the possibility to affect on the VMD. For instance, the locations with minimum VMDs, corresponding to Fig. 2-(a) and 2-(b), are fairly different from actual horizon, as shown in Fig. 2-(c) and 2-(d).

(a) (b)



(c) (d)

Figure 2. The limitation of conventional VMD-based horizon detection; (a-b) the results of minimum VMD detection method and (c-d) VMD

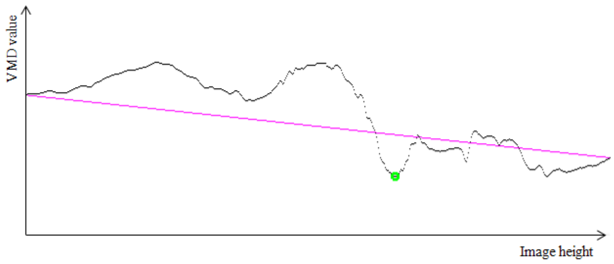
Since the region of road and sky is located in the bottom and top, a line, which connects between the top and bottom points, can be a reference line regardless of the cloud, obstacles and road sign in the image. The location that has maximum difference between this reference line and VMD value is considered a horizon location. The proposed algorithm is defined as follows:

$$\Delta VMD = \frac{VMD(H) - VMD(1)}{H} \tag{3}$$

$$Horizon = \underset{i}{argmax} \left| \Delta VMD * i + VMD(1) - VMD(i) \right| \quad if, VMD(i) < \Delta VMD * i + VMD(1), i \in (i,H) \tag{4}$$

where VMD(1) and VMD(H) are the average intensity value of the first and last rows in the scenes. Also, VMD(i) is the average intensity value of the i-th row and H is the height of the image. Fig.3 (a) and Fig.3 (b) are the result of the proposal method where green and markers are represent the location of the horizon.

(a)



(b)

Figure 3. Modified VMD-based horizon detection; (a) The result of the proposal method and (b) VMD

IV. Experimental Results

The simulation environments are the Visual Studio Community 2015, OpenCV 2.4.7 and Intel® Core ™ i5-3470 CUP @ 3.20GHz. In order to evaluate the performance of the algorithm, the malaga stereo and laser urban data set that provided by MRPT (Mobile Robot Programming Toolkit) is used as the test image sequence [4].

A. Information of Data Set

MRPT data set provides the image containing the various driving environments. Three scenarios are used in this simulation. Each clip consists of the variety environments such as the material of the road, weather, the traffic sign and etc., and the resolution of the image is 800*600 @ 30Hz. The additional information of the each scenario is demonstrated in the TABLE I.

TABLE I. Summary of the Clips

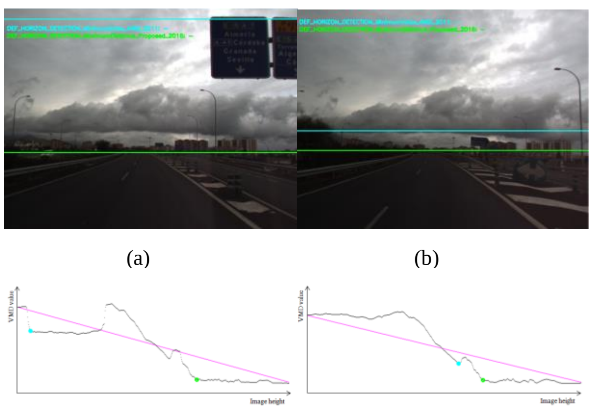
Clip	Summary	frames
Clip#2	*Through an under-construction road*	*800*
Clip#9	*Through the campus boulevard, with some traffic*	*800*
Clip#11	*High-way incorporation, some traffic*	*2,400*

B. Results and Analysis

The performance is evaluated by comparing the detected horizon position with the actual horizon position which set manually. The assessment was done only for the images that include the horizons. The performance of the conventional and proposal methods are summarized in TABLE II.

TABLE II. Results of Comparison

Clip	Distance of error pixel		A number of error frames	
	Proposal method	***Min. VMD***	***Proposal method***	***Min. VMD***
Avg.	*14.0*	*31.4*	*32.5*	*95.3*
Clip#2	*7.0*	*13.3*	*15.0*	*67.0*
Clip#9	*15.0*	*16.3*	*15.0*	*14.0*
Clip#11	*7.5*	*112.0*	*11.0*	*378*



(a) (b)

(c) (d)

Figure 4. Comparison of two method; (a-b) the results of the detection and (c-d) VMD

The typical situations with significant obstacles are given in Fig. 4. The cyan line and markers represent the conventional results and the green line and markers are the results of proposed algorithm. The traffic signs or clouds, respectively Fig. 4-(a) and 4-(b), affect on the VMD patterns, the conventional methods have a significant difference between the detection results and the actual horizon. Meanwhile, the proposal method can detect the actual horizon. These experimental results demonstrate that the proposed method is more robust and has high accuracy than the previous method.

V. Conclusion

In this paper, we propose an algorithm to perform an effective and robust horizon detection. This method is used for the vertical mean distribution of the image to determine the position of horizontal line. In order to improve the accuracy and robustness, we use the reference points that exist on the line between top and bottom of the VMD. By limiting the region of interest in the area below the horizon, we can reduce the calculation time when applying the other algorithm, such as the lane boundary detection, the recognition of the obstacles on the road, etc.

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